MULTILAYER HARD BIAS FILMS FOR LONGITUDINAL BIASING IN MAGNETORESISTIVE TRANSDUCER

FIELD OF THE INVENTION

This invention relates to magnetic transducers and in particular to thin film magnetoresistive assemblies.

BACKGROUND OF THE INVENTION

Inductive write heads are used for recording information on magnetic media, such as magnetic disks. The recorded information can be read out by an inductive read/write head. Alternatively, MR heads can be used for sensing signals which have been recorded on a magnetic medium. The signal sensed by an MR head is proportional to the magnetic flux associated with the recorded signal, and not to the rate of change of flux which is sensed by an inductive head. Thus an MR head can detect a magnetic field representing a recorded signal without any relative motion between the storage medium and the MR head.

A typical thin film MR head incorporates a single MR element, preferably made of a layer of Permalloy having an easy axis of magnetization. During operation of a data storage apparatus, such as a disk drive, an electric sense current is directed to the MR element. The magnetic field being sensed exerts a torque on the magnetic moment in the MR thin film causing a change in the resistivity of the film. The change in resistivity is proportional to the strength of the field being measured and causes variations in the resistance of the MR element. Detection of such variations provides a readout signal related to the data signal recorded on the magnetic medium.

FIG. **1** is a cross-sectional view of an embodiment of a prior art magnetoresistive (MR) transducer taken along a plane parallel to the air bearing surface (ABS) of the device. The MR transducer, designated by reference numeral **2**, comprises a tri-layer structure **4**. Included in the tri-layer structure **4** is a spacer layer **8** sandwiched between a magnetoresistive layer **6** and a soft magnetic adjacent layer **10**. The magnetoresistive layer **6** is normally made of a soft magnetic material, such as Permalloy which is an alloy of nickel and iron, having a high permeability and a low coercive force. During the read process, changes in magnetic flux passing through the magnetoresistive layer **6** correspondingly vary the resistivity of the magnetoresistive layer **6**. As is well-known in the art, the magnetoresistive layer **6** must be aligned in a single domain-state to suppress the Barkhausen noise. Hard magnetic layers **12** and **14** disposed at the end portions of the tri-layer structure **4** fulfill this function by cooperatively providing a longitudinal magnetic bias for magnetic domain alignment. Moreover, for magnetoresistive layer **6** to operate within a linear region, another bias, called the transverse magnetic bias, must also be applied to magnetoresistive layer **6**. The soft adjacent layer **10** carries out this duty by providing the required magnetic bias.

Hard magnetic layers **12** and **14** are permanently magnetized and are disposed in direct contact with the end portions of the magnetoresistive layer **6**. Hard magnetic layers **12** and **14** supply the longitudinal magnetic bias to magnetoresistive layer **6** through a process called magnetic coupling. The soft adjacent layer **10**, generally made of a soft magnetic material having a high permeability, a low coercive force and a high resistivity, branches out a fraction of the bias current applied across electrical leads **16** and **18** during normal operations. The branched out current induces a magnetic flux which traverses the magnetoresistive layer **6** as the transverse magnetic bias.

During the read mode, the bias current applied across electrical leads or conductors passes through the magnetoresistive layer **6** via the hard-magnetic layers **12** and **14**. Changes in the magnetic flux intercepted by the transducer **2** vary the electrical resistivity of the magnetoresistive layer **6**. The bias current flowing through the magnetoresistive layer **6** with varying resistivity accordingly generates a varying voltage. The varying voltage corresponds to the information read out from the storage medium (not shown). Transducers of this type are described in U.S. Pat. No. 4,639,806, entitled "Thin Film Magnetic Head Having a Magnetized Ferromagnetic Film on the MR Element", Kira et al., issued Jan. 27, 1987.

FIG. **2** shows another type of prior art magnetic transducer designated by reference numeral **20** which is quite similar in structure to transducer **2** shown in FIG. **1**. However, there are underlayers **22** and **24** disposed between hard magnetic layers **12** and **14**, respectively, and the end portions of magnetoresistive layer **6**. Underlayers **22** and **24** are typically made of a non-magnetic material and serve to prevent magnetic coupling between hard-magnetic layers **12** and **14** and magnetoresistive layer **6**. Underlayers **22** and **24** also provide the function of preserving a desirable orientation of the crystalline structure of the hard magnetic layers **12** and **14** during the fabrication process. The required longitudinal magnetic bias to the magnetoresistive layer **6** is supplied by hard magnetic layers **12** and **14** through a process called magnetostatic interaction. Transducers of this type are described in U.S. Pat. No. 5,005,096, entitled "Magnetoresistive Read Transducer Having Hard Magnetic Shunt Bias", Krounbi et al, issued Apr. 2, 1991.

To further improve the longitudinal magnetic bias, a different type of transducer is devised. FIG. **3** shows such a prior art transducer designated by reference numeral **26**. In transducer **26**, hard-magnetic bias layers **28** and **30** form abutting contacts with magnetoresistive layer **6** through abutting junctions **32** and **34**, respectively. Hard-magnetic layers **28** and **30** provide a more continuous longitudinal magnetic bias to the magnetoresistive layer **6**, in comparison with the transducers **2** and **20** shown in FIGS. **1** and **2**, respectively. It should be noted that the thickness t_h of hard magnetic layers **28** and **30** is comparable in dimension with the corresponding thickness t_s of the tri-layer structure **4'**. As a consequence, transducer **26** also realizes another important advantage, namely, the overlying magnetic shield and the dielectric layer (not shown) can be deposited atop the transducer **20** with improved step coverage. That is, the aforementioned overlying layers can be deposited with less steep steps, thereby minimizing the chance of generating electrical shorts between the electrical leads **16** and **18** and the upper magnetic shield layer. There are a number of operational similarities between transducer **26** and transducers **2** and **20**. As with the transducer **20** described above, non-magnetic underlayers **36** and **38** can be disposed between the respective hard-magnetic layers **28** and **30** and the magnetoresistive layer **6**. In this case, hard magnetic layers **28** and **30** provide the longitudinal magnetic bias via the